PERGAMON

Renewable and Sustainable Energy Reviews
2 (1998) 189–234

RENEWABLE
& SUSTAINABLE
ENERGY REVIEWS

Chapter 8—Technology for modern architecture

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The instinctive attention to how humankind interacts with the environment underwent a brusque inversion with the advent of the Industrial Revolution, when the generally more widespread availability of energy and the evolution of techniques and materials supported the Positivist illusion that technology could dominate nature and open the way to a series of transformations that would somehow be worked independent of environmental conditions and the possibilities for rational use of resources; and today, in the industrialized economies, this link with the environment almost always works in one direction only: nature as object, the field of application for the building industries, and only rarely as a planning parameter in and of itself and a term of comparison for an ethical as well as architectural judgement of the results of this activity.

We are well aware that there exists a pressing need to improve the performance and the quality of buildings; and in this sense, great progress has been made in the field of energy limitation from both the theoretical viewpoint and as regards testing and the reliable performance of components.

Buildings are increasingly more complex, especially from the standpoint of infrastructures and the services that relate to them, and as a result professional figures, who traditionally intervened in the building process only at later stages, are now involved even during the design phase: today's building customer requires consultants who are experts not only on architectural issues but also as regards infrastructures, energy, environment and the management of the building process itself. One could say that in the aftermath of the energy crisis and the information revolution, the relationship between the formal aspect of architecture and those related to energy has been reinverted, and that in many cases the latter aspects are those that lead project development as well as those which define its visible form.

This may be efficiently achieved if our approach to design is multi-disciplinary and as such permits the control, from inception, of each of the various project components, through integrating the contributions of the different techniques that form the overall

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PII: S1364–0321(98)00016–1

conception, each as regards its specific field of application. The result of such integrated cooperative work approaches the holistic concept of the phenomenon of transformation and can generate a product that is somewhat more complex than merely the simple sum of its components.

This chapter presents new technologies and innovative building elements in contemporary architecture. By means of introductory comments and the use of realised and projected examples there is an attempt to demonstrate the role which technology plays in modern architecture. These examples range from residential buildings to research centres and office complexes to religious buildings, and display not only the technical but also the philosophical, aesthetic and environmental issues encompassed by the realm of modern technology.

1. Ventilated roofs

The major part of the summer sun's heat falls on the roof of a building, due to its position with respect to the sun and has frequently to be protected to avoid overheating the spaces beneath. However, in the summer it is also the surface of the building which releases most heat through radiation to the night sky and these two characteristics are those which can be utilised to improve the internal microclimate.

The idea of the ventilated roof is certainly not new, as is the case with most architectural solutions; and numerous examples of its application are to be found in traditional buildings. In hot and temperate climates roofs in clay tiles, which because of the pitch with which they were made, were effective in keeping water away from their wooden structures beneath whilst at the same time reducing overheating for the occupants within. In nordic countries, solutions were developed to satisfy the need to isolate the interior from contact with the snow-covered roof which involved the use of ventilated air spaces.

Many contemporary architects, including Ralph Erskine, have adopted these solutions whilst utilising advanced technology and non-traditional materials. The typology of the double roof can, moreover, perform numerous functions other than that of sheltering the building from the sun's rays: the positioning of ventilation openings on opposite sides, or a system of forced ventilation can succeed in dissipating a large part of the built-up heat, especially if combined with evoporative cooling techniques. During the winter the option of closing the ventilation openings augments the insulation capacity of the roof and reduces heat losses.

The roof, since it receives such a high level of solar radiation must provide adequate insulation with the minimum mass possible so that it, in itself, is not a thermal mass which is capable of absorbing heat and thereby transmitting it to the spaces beneath. Moreover the roof comprises other physical characteristics which may be exploited for natural climatisation: during the night horizontal surfaces radiate heat to the sky and this constitutes a good method of thermal dispersion. The possibility of varying the external layers (with mobile insulation panels, reflective elements, movable roof elements, etc.) is an effective way to exploit the climatic variations in order to improve the energy behaviour of the building.

The optimal position for an absorption system on a roof is naturally the south-facing side. In the lower latitudes the winter sun has a sufficient elevation to give adequate solar absorption even on a horizontal plane; for higher latitudes the optimal configuration of the collector should be inclined, since the path of the sun is lower in the sky. In order to augment the solar advantage of a horizontal thermal mass, reflective surfaces in inclined positions may also be used. This may be obtained by utilising stepped south-facing planar surfaces and the use of movable elements which in the open position function as reflectors. Another solution consists of the application of movable insulation-reflection panels and function as a large reflective mirror which opens due south.

In a different way to solar absorption, the optimal configuration for cooling involves exposing a horizontal thermal mass to the night-sky. If the cooling load is greater and/or the climatic conditions are not ideal, the external surface may be sprayed with water, in this way the heat loss due to conventional nocturnal radiation has the added considerable cooling effect of evaporation; a thermal mass may, by evaporation, lose two or three times the heat lost through radiation.

The roof typology with a movable structure, although conceptually similar presents many different applications between them varying from large scale solutions, such as the Skydome stadium in Toronto where entire sections of the space-framed roofs open like enormous sails until the entire playing field is uncovered, to small buildings which utilise a simple opening and ventilation system for the assembly spaces, to experimental residential designs which are sheltered beneath a retractable roof.

The study of roofs and their possible utilisation in bioclimatic terms assumes a particular importance in industrial and commercial structures: the most common typology in this category is that where the roof is the dominant feature covering a single storey as opposed to residential and office buildings. The possibility of direct high-level internal illumination of buildings such as museums, factories and supermarkets presents interesting possibilities which have also, in the past, received the attention of many famous architects, from the Le Corbusier project for the Venice Hospital, the churches of Alvar Aalto, to the Menil museum of Renzo Piano.

The contemporary possibility of placing the bearing structure of a building on the outside has made possible uninterupted internal space, allowing the utilisation of vertical and horizontal load-bearing elements as supports for the fixed or mobile shading components helping to avoid summertime overheating by reducing the direct radiation on the glazed elements. The presence of an external structure also allows the utilisation of different construction systems in the interior of the same building as in many of the projects by Hopkins, from the Schlumberger Research Centre, to the roof of the Mountstand cricket stadium where the bearing columns of the platform also provide the restraining points for the tensile structure of the roof.

The roof typology may be modified for applications in different climatic contexts, according to the prevailing problems. In temperate or hot climates one seeks to reduce the transparent part and augment that which is opaque, giving particular attention to the possibility of natural ventilation as, for example, in the supermarket by Mario Botta in Florence, the office building at Montecchio by Renzo Piano or the Danish Pavilion at the Seville Expo. In temperate-cold climates the roof constitutes a barrier

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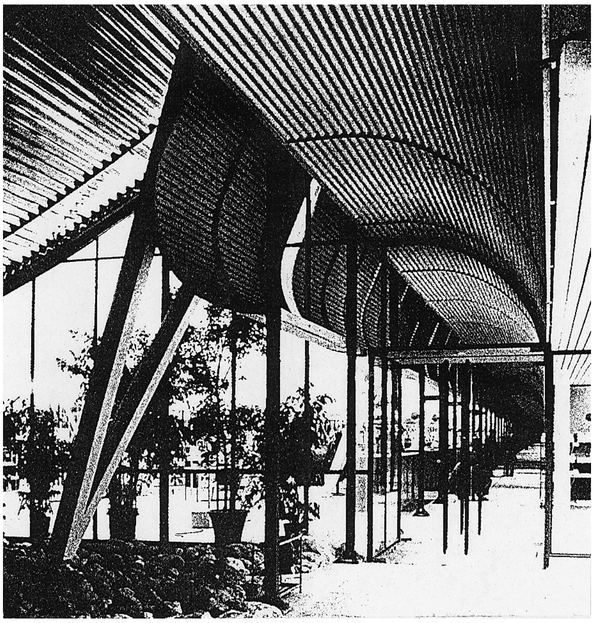


(b)

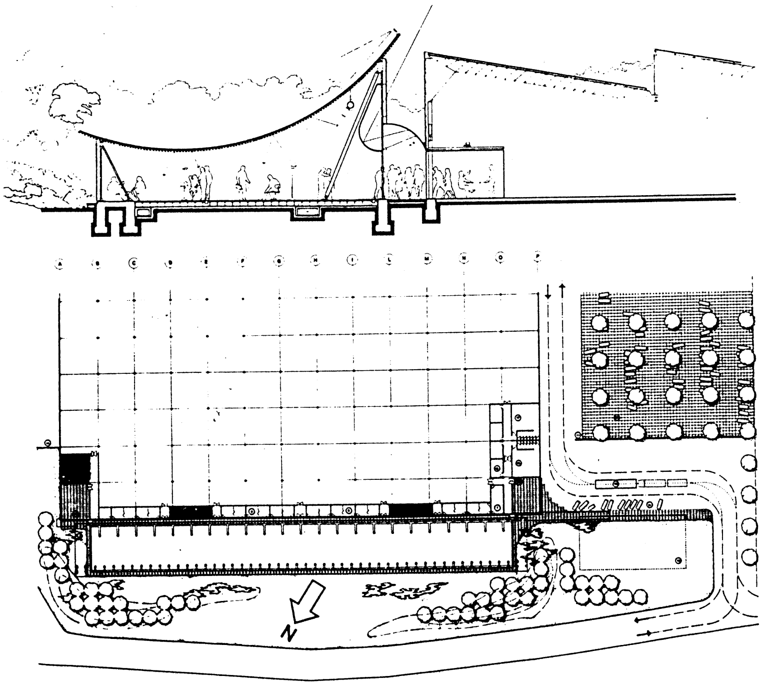


Fig. 1. *Office building*, *Montecchio*, *Italy* (Renzo Piano, Architect). (a) The curved roof cladding has a constant section and it is constituted by steel frames with a thick complementary concrete layer and insulation. (b) Plan and section of the project.

(c)

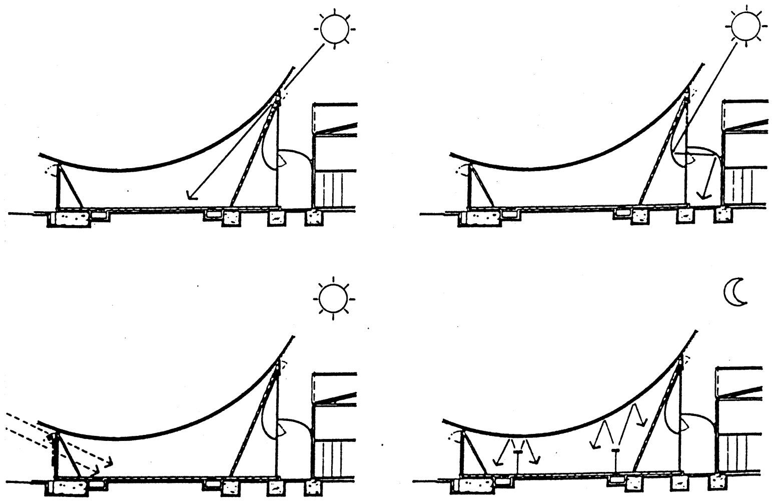


Fig. 1(c). Bioclimatic schemes.

Schlumberger Research Laboratories, Cambridge

Michael Hopkins and Partners

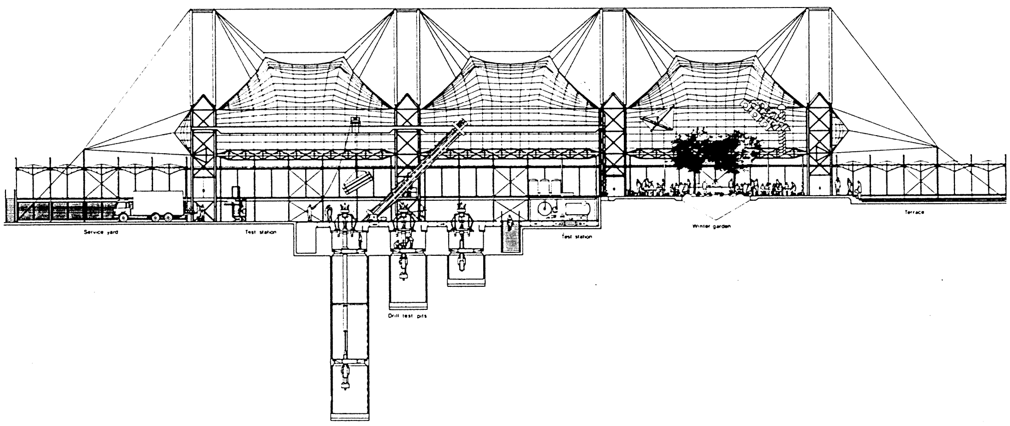


Fig. 2. *Schlumberger research centre*, *Cambridge*, *U.K.* (Michael Hopkins Association). (a) Section.

against heat loss and as a source of natural light, with devices to eliminate thermal bridges and maximise energy gains.

1.1. *Office building, Montecchio, Italy (Renzo Piano architect)*

The building is developed off a central spine passage-way, dividing the offices from the service areas that act as a buffer to the nearby factory. The supporting structure for the roof is formed by paired asymmetrical trestles in I-profiles with hinge joints to the curved beams and to the fixings set into the concrete floor. The curved roof of the building is in profiled metal with impervious and insulating layers. The perimeter panels are completely glazed and allow a transparency between inside and out and office and factory. The distribution of natural light to the interior is assisted by the curved reflective screens which utilise the higher part of the roof sail as a light collector.

1.2. *Schlumberger Research Centre, Cambridge, UK (Michael Hopkins Assoc.)*

The building houses a research centre for petrochemical platforms; in plan it takes the form of a H with offices to either side, the research areas, experimental laboratories and testing hall in the centre, and the entrances on the sunken sides. A large glasshouse on the south wall houses a restaurant and meeting space. The roofs of the offices are made up of trusses whilst the central part is covered by a large translucent glass-fibre membrane, coated in Teflon and suspended from steel cables which form an external structural web. This structure is tied back to pylons in tubular steel, carrying a triangular section truss spanning 19.2 m. The semi-transparency of the roof allows the occupants an idea of the time of day and the weather. The membrane was fixed on site to the trusses.

2. Active curtain wall

Energy-conscious design is but one of the responsibilities of the modern designer requiring an understanding of the building envelope as a layer which has a variable dimension and whose active role is defined by the harshness of the climate in which the building is placed. A large section of contemporary research is directed towards innovations in the field of active curtain walling with the aim of producing automatically controlled intelligent facade components capable of monitoring the internal and external climatic conditions and then reacting in the appropriate manner. This may be used in conjunction with a general energy reduction philosophy to provide a comfortable indoor environment at low energy and environmental cost. This new architectural emphasis has generated a high degree of advanced technological design in contemporary building which may be seen in built-up areas: the intelligent building is a reality to which we must become accustomed since it involves the reconsideration of alternative energy.

The development of curtain walling was a natural progression of the historical understanding of a facade as a wrapping for a building with the dual function of

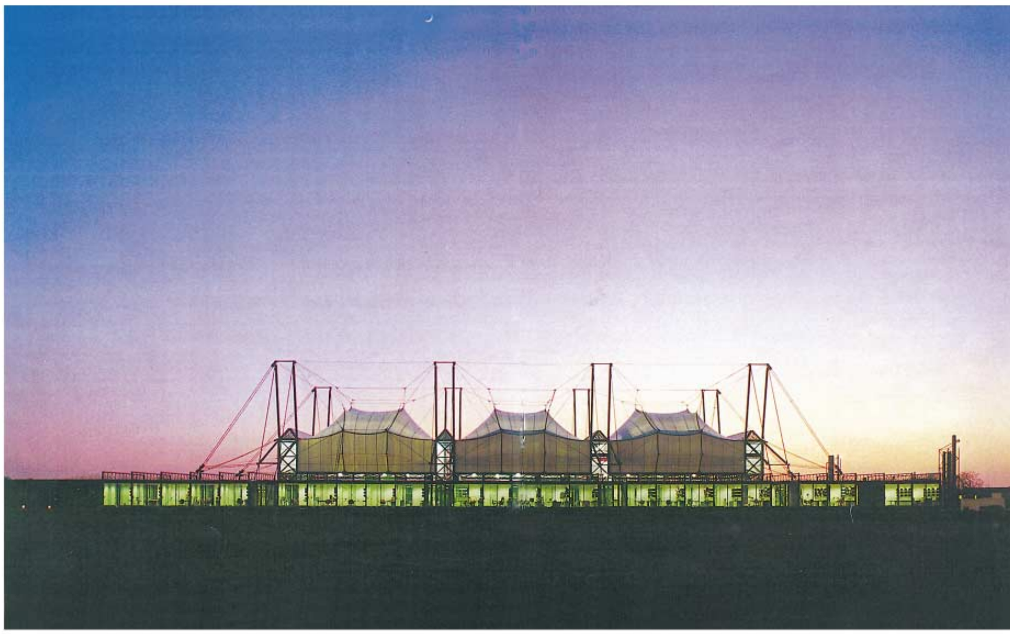


Fig. 2(b). Fabric roofs stretched by wires held by steel pylons.

(a)

(c)

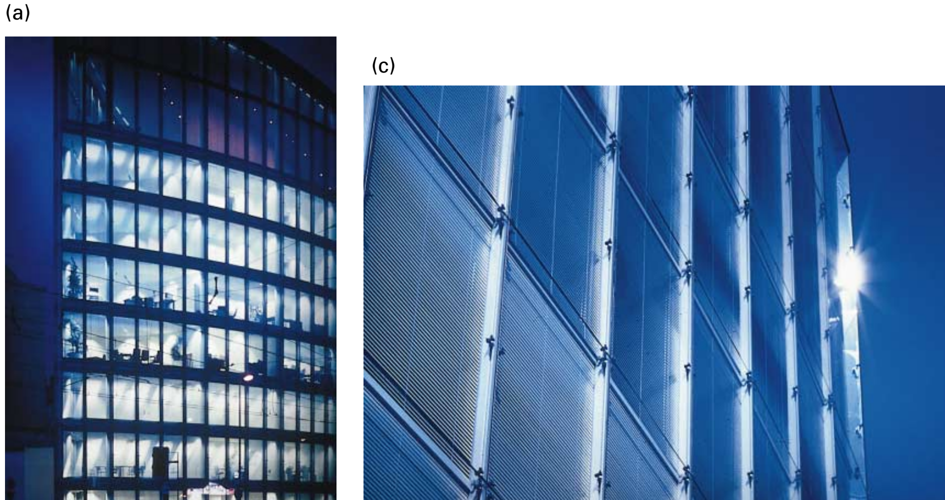


Fig. 3. *Business Promotion Centre*, *Duisburg*, *Germany* (Sir Norman Foster and Partners). (a) The seven-storey Business Promotion Centre is a landmark building which hopes to regenerate business and promote growth in the Ruhr area. (c). The triple layered cladding system uses computer controlled blinds.

(a)

(b)

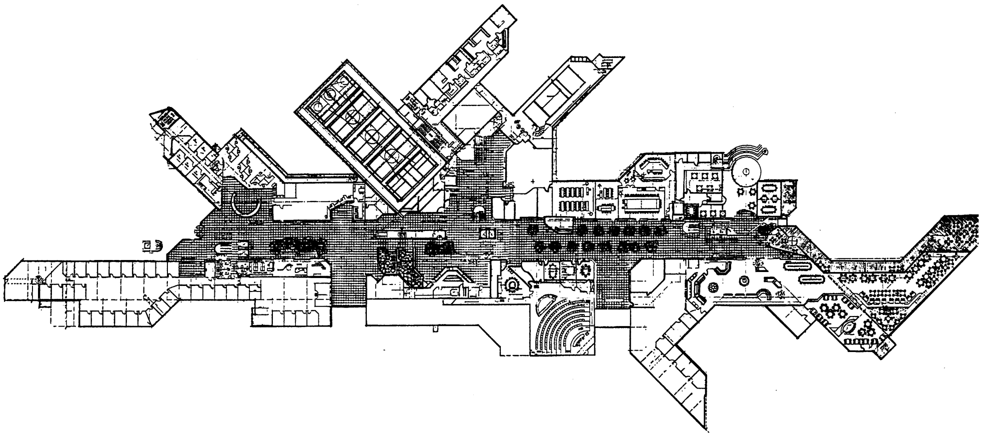


Fig. 4. *S.A.S. head office*, *Frosundavik*, *Sweden* (Niels A. Torp). (a) Instead of projecting the building into the seashore zone to create a feeling of contact with the water, the seashore itself was drawn in towards the building in the form of a small "lake". (b) Plan of the project. The main idea was to give the impression of a new dimension, that the curtain wall "hovers" in front of the building. (c). The SAS Administration Building is intended as a kind of village which, together with the SAS employees, will make up a small living community in its own right. (d). In the street area variations and contrasts are created by the play of incoming daylight from sunrise to sunset and evening.

Fig. 4. Continued.

Fig. 5. *Domilens laboratories*, *France* (Del Sud Associates). (a) The interior veranda housing the large garden with natural light from the glazed surfaces. This glasshouse effect allows the environments to be enjoyed to the full, as well as offering particularly favourable working conditions.

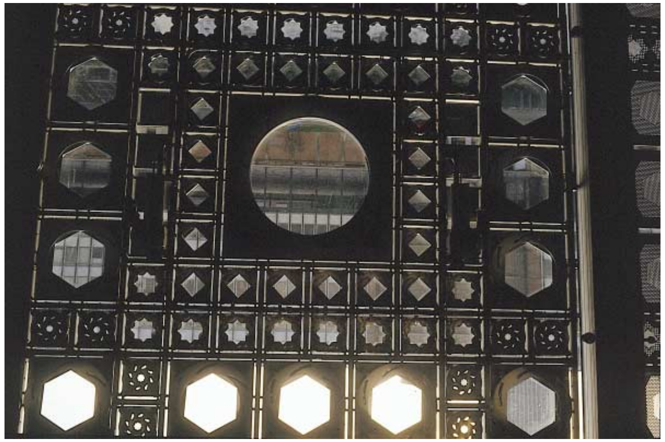


Fig. 6. *The Institute of Arabian Affairs*, *Paris*, *France* (Jean Nouvel). (top left) The south side that echoes Arab architectural features. (top right) The view from the inside is screened by a variable pattern based on the principle of the camera diaphragm—the aperture is regulated by means of photo-electric cells to control the amount of light filtering into the room. (left & right) The transparencies, the superimposition of frames and materials follow a technical pattern without excess, perfectly mastered.

Fig. 8. *Belgian Pavillion*, *Seville*, *Spain* (Driesen–Meersman–Thomaes). (a) The Belgian pavilion may be considered as a large courtyard, on the outside protected from the sun by a system of screens. (b) A column structure based on a 10×10 m module supports the surrounding sun screen system and the exhibition building, the containers, sheds, balcony, staircase and walkways. (c) Sun-protecting fabric wings on front walls.

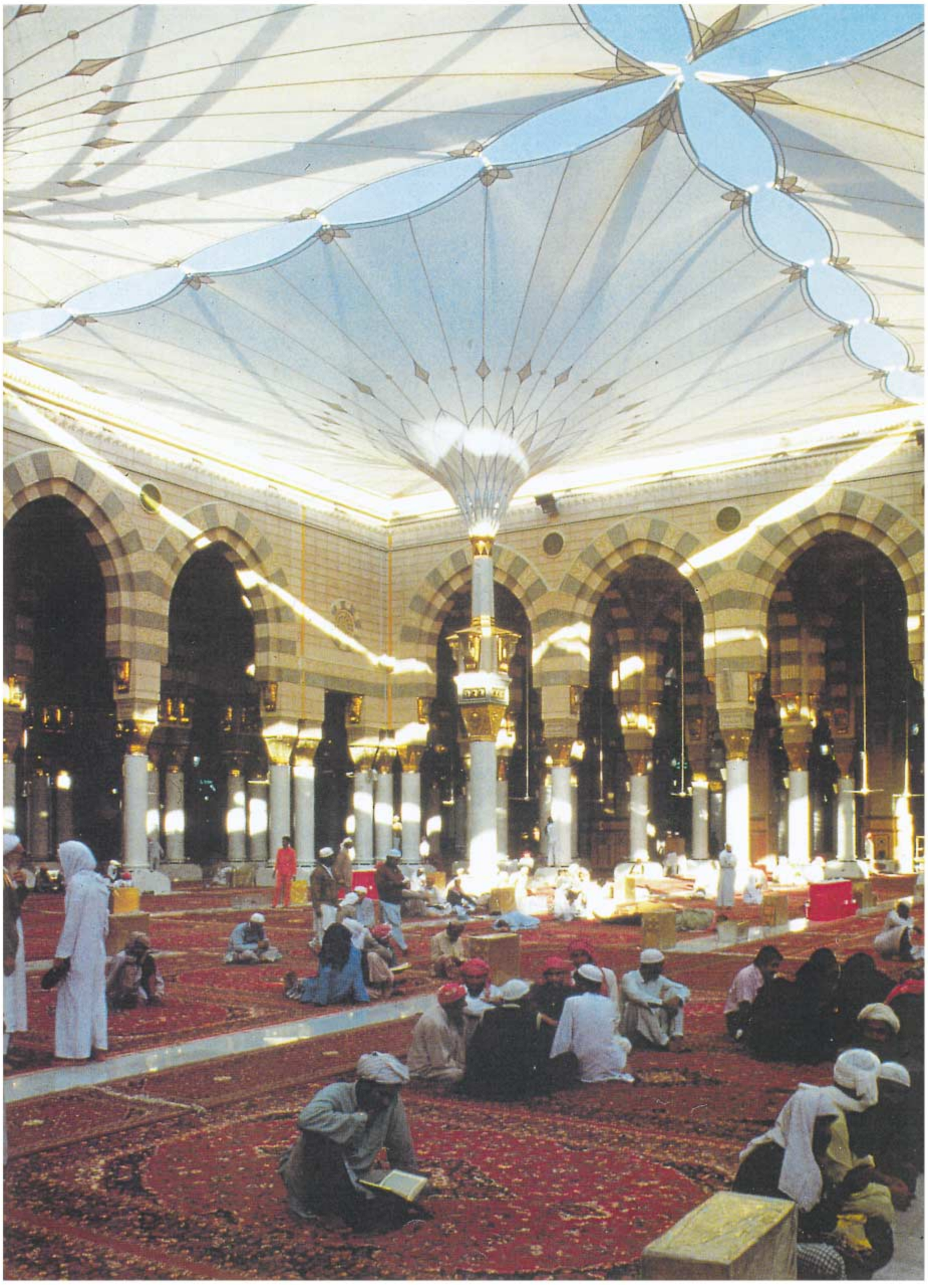


Fig. 9. *Extension of the Sacred Mosque of the Prophet at Medina, Saudi Arabia* (SL GMBH Rasch and Associates). (a) When the umbrellas are opened, they reveal their gathered membranes to create a lightweight vault.

Fig. 10. *British Council*, *Madrid*, *Spain* (Jestico and Whiles). (a) Exploded axonometry. To ameliorate poor internal air circulation and lack of daylighting an inverted cone deeply penetrates the building.

Fig. 11. *Hong Kong Shanghai Bank*, *Hong Kong* (Foster Associates). The suspension structure in asymmetrical trusses: the ''short'' part of the hanger holding up the service modules and escape stairs; the ''long'' part holding up the central floor spans. The vaste banking hall atrium where natural lighting is increased by a sophisticated array of movable mirrors powered by a computer-controlled electric motor.

(a) (b)

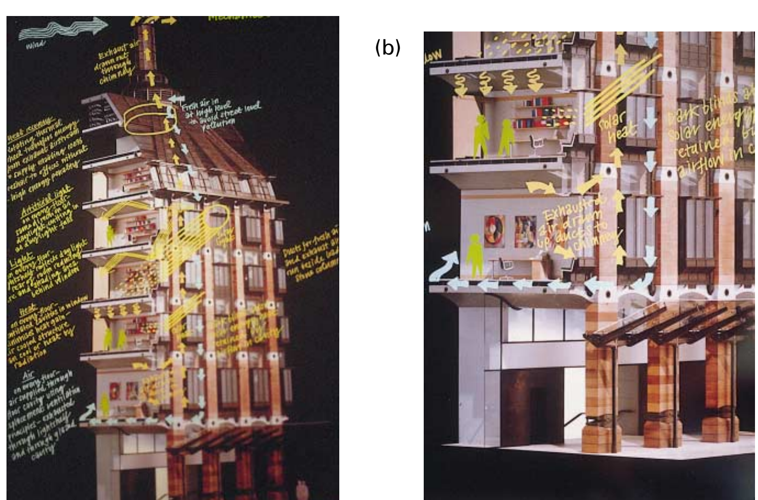
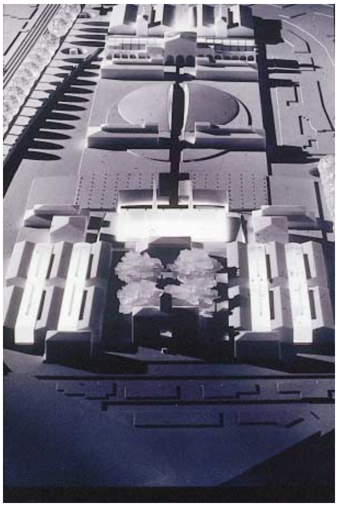


Fig. 12. *New Parliamentary Building at Westminster*, *U.K.* (Michael Hopkins and Partners). (a) Axonometric view. Particular daylighting and ventilation systems have been adopted in the project. Exhaust air is drawn up through chimneys on top of the building. (b) The vaulted ceiling, constituted by precast concrete elements, is used as a thermal mass. The daylighting contribution is increased by reflectants elements on ceiling, which utilisation is connected to the one of the external brises-soleil.

(a)



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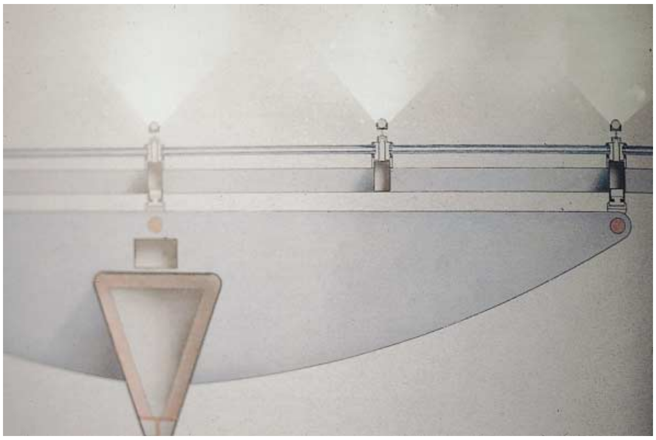


Fig. 14. *National Museum of Natural Sciences*, *Florence*, *Italy* (L. Macci, G. Maggiora, A. Breschi, A. Cortesi, M. Moretti, M. Sala). (left) View of the complex.

(a)

Fig. 15. *British Pavilion*, *Expo* 92, *Seville*, *Spain* (Nicholas Grimshaw). (a) The buildings within a building idea is more than just a way to preserve the impressive unity of the interior. It is also a clear architectural expression of the energy conservation strategy of the building.

(b)

(c)

(d)

Fig. 15. (b) On the roof of the building the cooling device takes the form of a series of elegant, double-curved, linear-fabric structures, rised up above the flat roof itself on V-shaped steel struts. (c) The most impressive of this device is the "water wall" of the East facade. A sheer glass curtain wall, with no projecting mullions or transoms, supports a continuous sheet of water falling into a pool, half inside and half outside the building. (d) Within the dominant, "cathedral-like" space apparently free-standing accommodational "poods" provide special spaces for audio-visual presentations and the like. Circulation between the poods and platforms is via a system of bridges and ramped travelators.

(a)

(b)

(c)

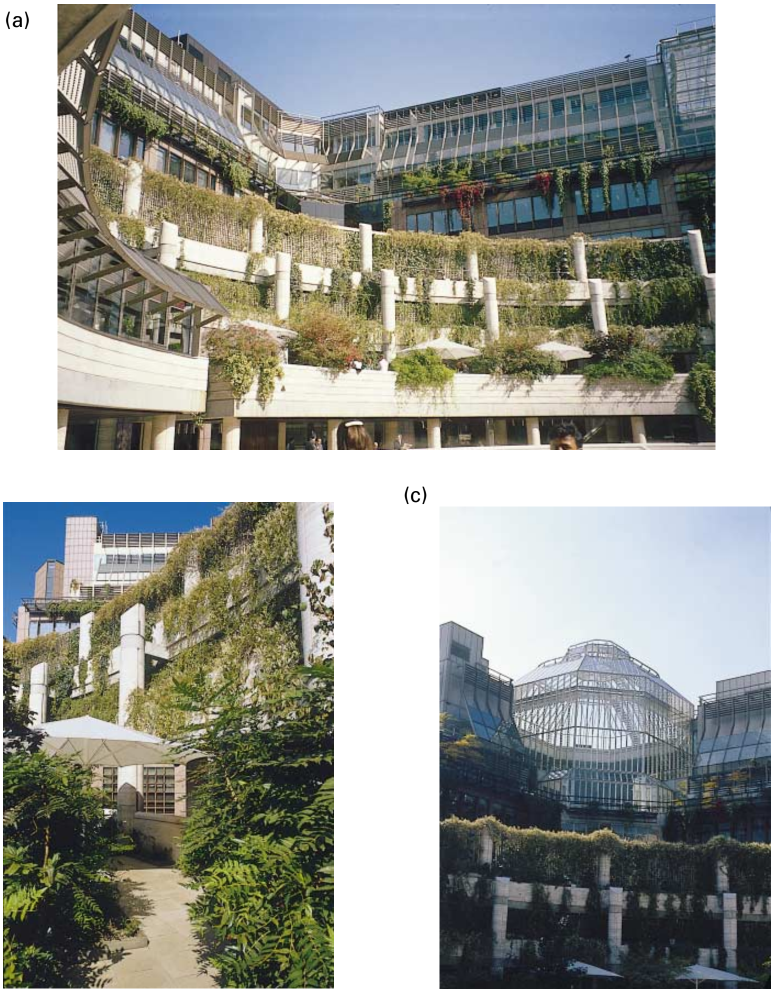


Fig. 16. *Shopping centre and offices in Finsbury Avenue*, *London*, *U.K.* (Ove Arup Associates). (top) Based around a closed internal courtyard, the offices also look on to the surrounding city streets. (left) The theatrical image of the pergola and other ramping levels contribute to the creation of small terraces on the structure of a green oasis. (right) Far above the floor is a fretwork of steel roofing that owes its origin to buildings such as the mid-Victorian iron and glass Temperate House at Kew Gardens.

(a)

(b)

Fig. 17. *El Palenque*, *exhibition structure*, *Expo '92*, *Seville*, *Spain* (J. M. De La Prada Poole). (a) The Palenque is an area of 8000 mq including a space for shows with capacity for 1500 spectators, together with other areas for restaurants and shops. (b) The white PVC covering (13% transmissivity) has a controlled irrigation system to avoid the overheating of the external side and the re-irradiation to the spaces below.

(c)

Fig. 17. (c) On top of each conical structure is a warm air exhause opening combined with an evaporative cooling system to create an evaporative tower.

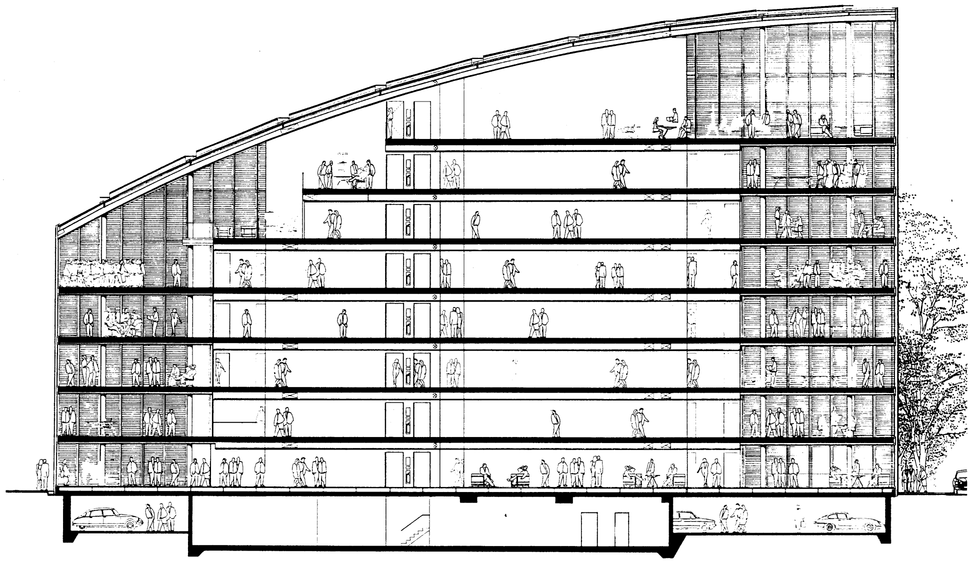


Fig. 3(b). Section. The building is clad with a triple skin comprising Pilkington Planar glazing, computer controlled blinds and a transparent inner layer to moderate extremes of outside temperatures.

climate moderation and aesthetic representation and found its initial expression in the industrial architecture of the turn of the century.

The freedom given by the availability of new materials making it possible to replace opaque masonry with transparent glazed walls proved revolutionary, heralding a new light filled architecture. It was only after the indiscriminate glazing of the 50s and 60s with its detrimental effects on the internal built environment and the oil crisis of the early 1970s that pressure was exerted to improve the thermal performance of glazing systems.

In order that curtain walling be considered as a practical alternative to traditional building techniques it ought to possess comparable characteristics. The basic requirements of any building facade as that of a climate modifier include the admission of light and its control, the provision of a reasonable layer of insulation, natural ventilation and cooling, resistance to external forces and the possibility of integrating different components. Modern curtain walling systems, often chosen for their aesthetic qualities or lower construction cost must also evolve to include these qualities, since, as experience has proven, it is far more expensive, and in many cases impossible, to upgrade existing curtain walling systems than it is traditional construction typologies.

By modifying the characteristics of window elements their thermal and lighting performances may be improved. Components operating under neural network control reduce heat losses by infra-red radiation and operate mechanical ventilation for cooling internal spaces.

In addition to building facade aesthetic, the functional requirements of curtain walling may be described as solar gain control, daylight and ventilation control, cost

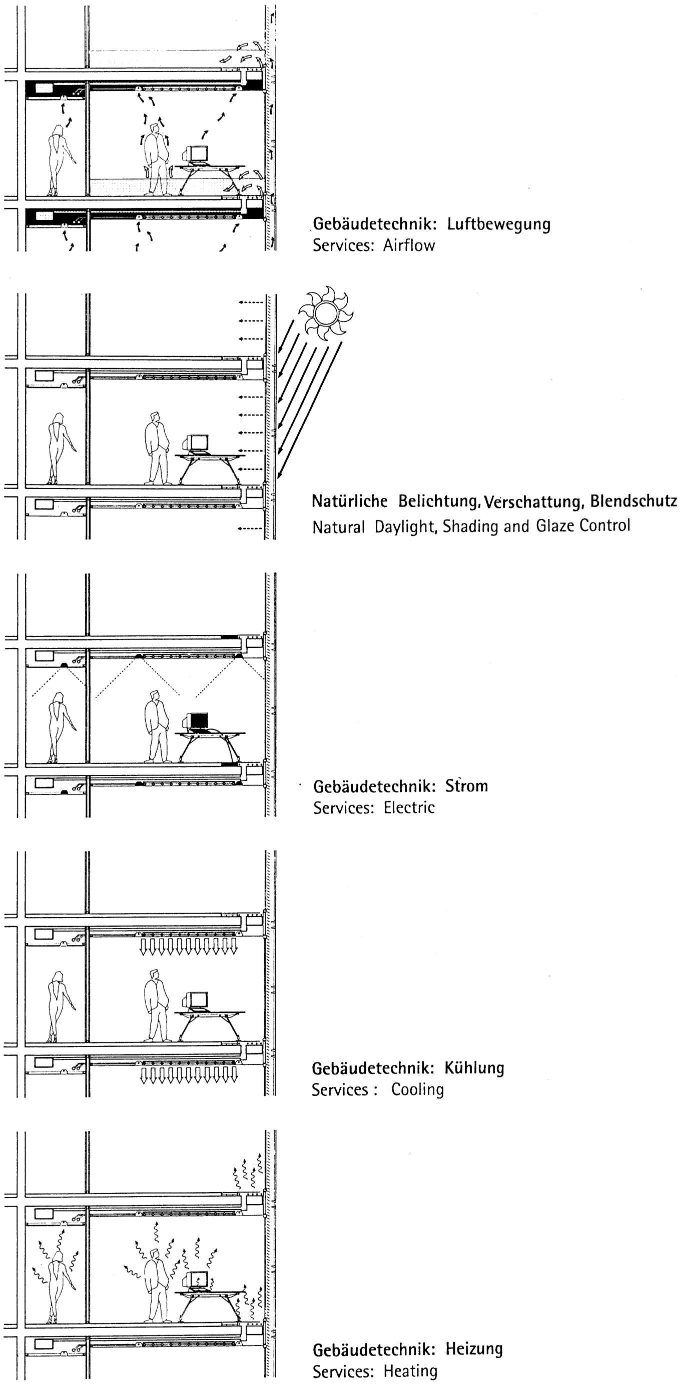
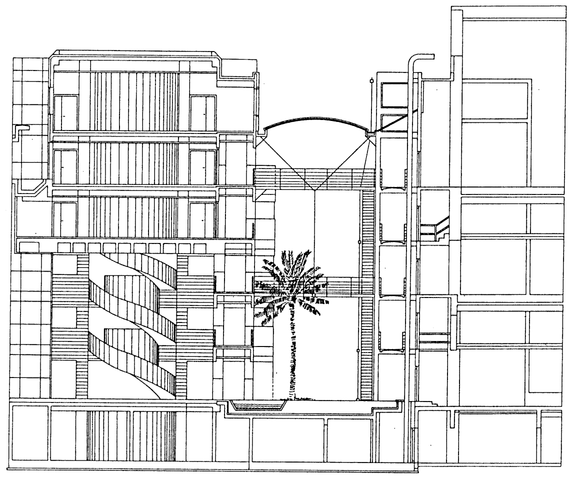


Fig. 3(d). Section. Integrated services.

(b)



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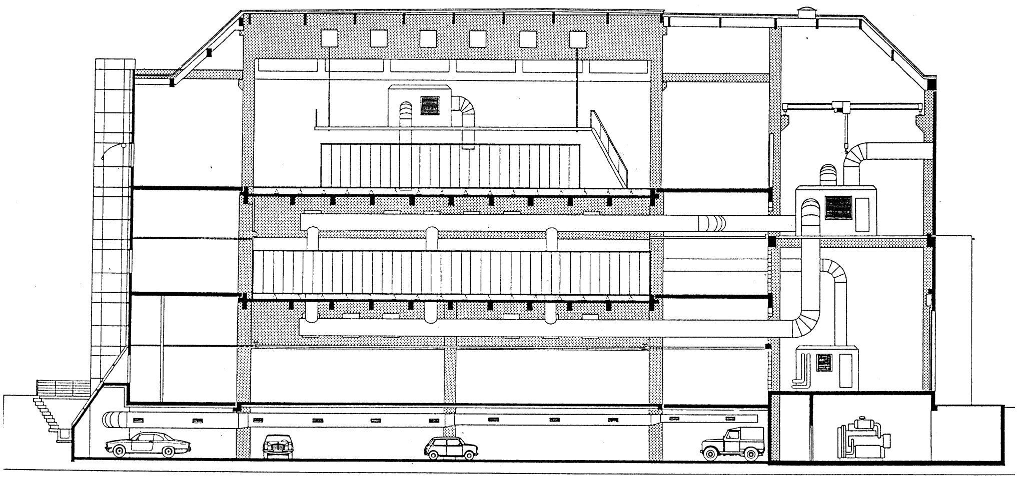
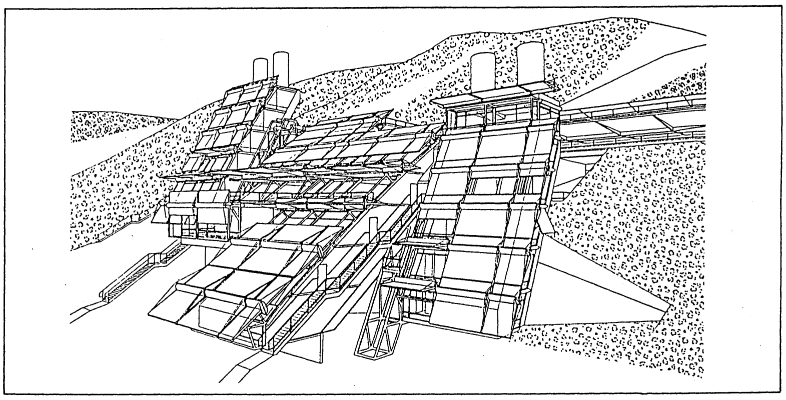


Fig. 5(b). Cross-section on the vast atrium with the articulated distribution of stairs and walkways. (c). Longitudinal section. The exposed technological structures become a characteristic element of the architectural composition of the building.

savings in heating or air-conditioning and automatic adjustment by neural network systems. Facade devices acting as an intelligent interface between indoors and outdoors installed on the 'skin' of the building provide the appropriate thermal insulation and air-exchanges necessary for improving internal conditions. Where coupled with transparent insulation materials with good optical performances and transmission switching, these devices may act as efficient solar air collectors, as controllable, nightly

(a)



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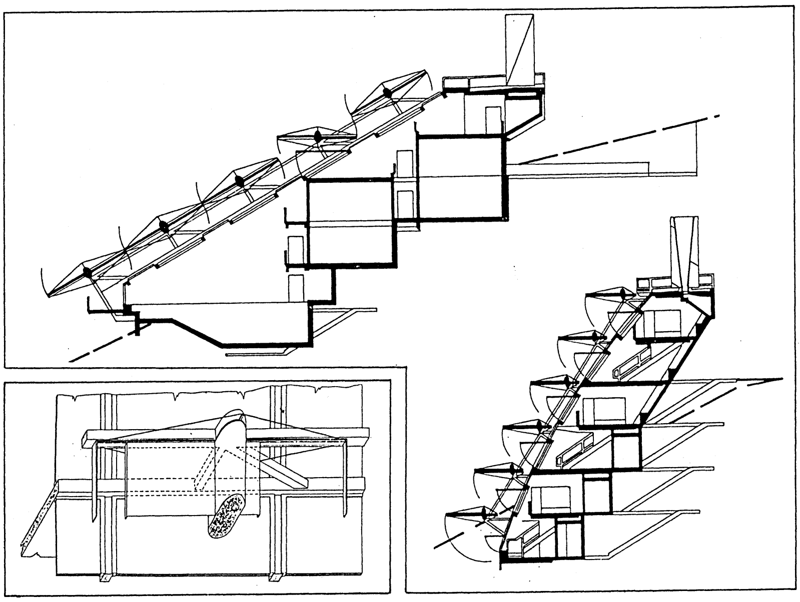

Fig. 7. *Residential building, Malibu, California, U.S.A.* (A.A.V. Architects). (a) Perspective view of the south facade. (b) Cross-section. The access of light into inner rooms is mechanically controlled with brises-soleil.

insulated direct-gain windows and as air exchangers, selecting automatically the appropriate function changing with the the external environmental conditions.

Neural network technology mimics the problem solving process of the brain, applying previously gained knowledge to new problems or situations, thereby developing an ability to read each different situation and consequently 'conducting' the system's various components to take the appropriate action.

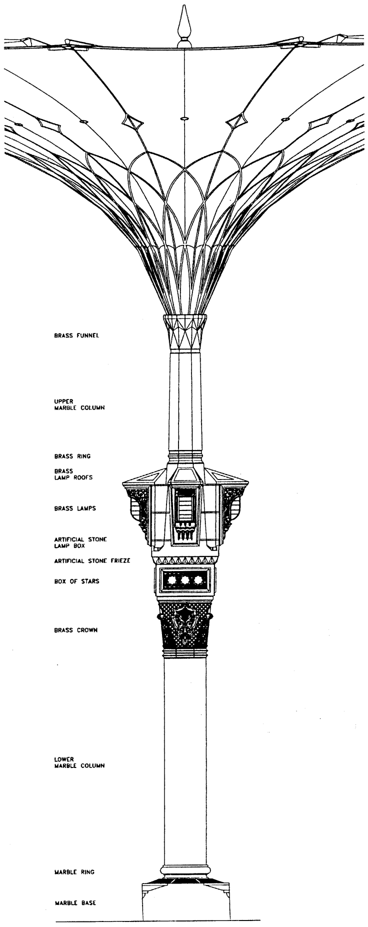

Fig. 9(b). Vertical elevation. The supporting columns are mainly in marble, with copper and artificial stone inserted into the capitals where the lamps and air outlets are installed.

2.1. *Business Promotion Centre, Duisburg, Germany* (*Sir Norman Foster and Partners*)

Positioned at the entrance of a long axial park connecting the city of Duisburg with the University, the elegantly curving form of the glazed Business Promotional Centre has become the most potent urban sign of the entire development. The seven-storey Business Centre is a collaboration with Kaiserbautecnik, environmental engineers also acting as private developer. It is a landmark building which hopes to regenerate business and promote growth in the Ruhr area. The ground floor contains a banking and exhibition hall in a double height space; office and conference spaces occupy the

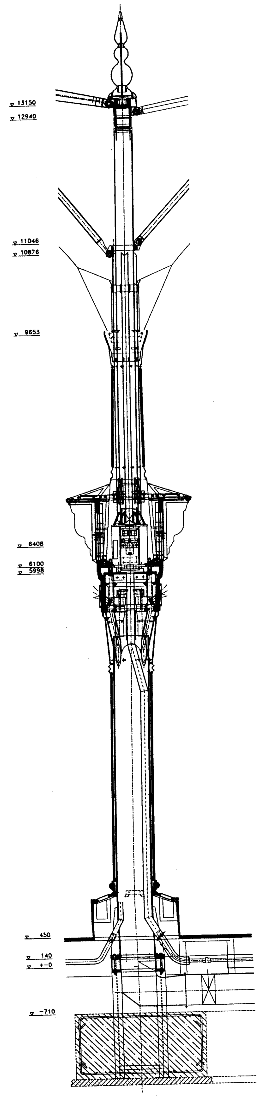

Fig. 9(c). Vertical section. Each umbrella has four lamps integrated into the claddings above the column capital which illuminate the courts at night, and two air outlets linked to the building's air conditioning system.

remaining area and terminate in a grand three storey terrace which can be rented for suitable commercial purposes.

High quality architecture, bordering on sculpture in glass, it is part of a new generation of electronically controlled buildings which provide a high level of environmental comfort in the work-place. The triple layered cladding system uses computer

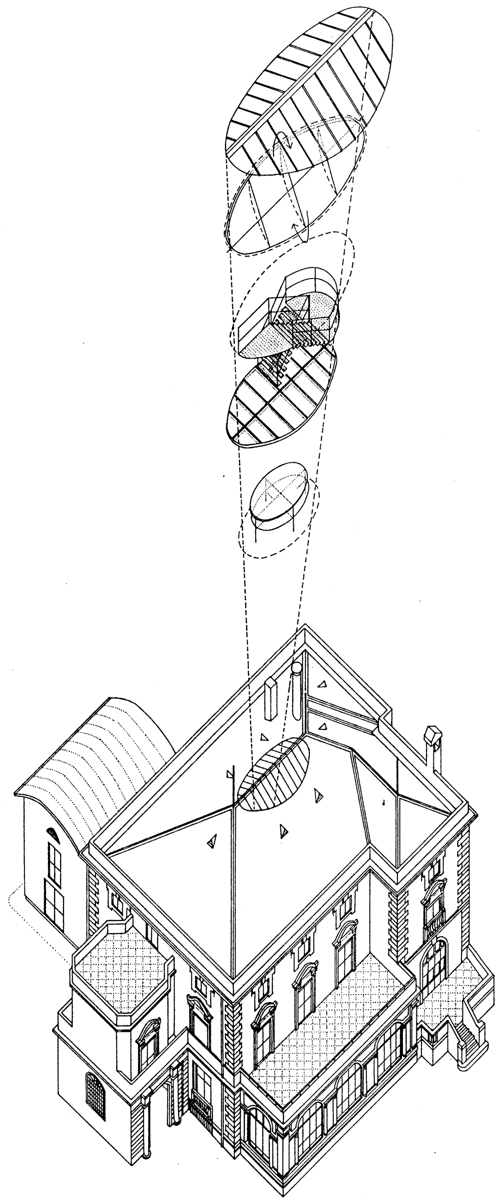

Fig. 10(b). Comprising new lightweight stair topped by a glazed rooflight, this area provides a focus for the users' activities. Excessive solar gain is prevented by a diaphragm blind.

controlled blinds by Kaiserbautecnik: an individual control panel modifies the thermal and visual comfort in each room allowing the user to control temperature and light by adjusting the light sensitive shading in the transparent cladding: this panel is part

(a)

(b)

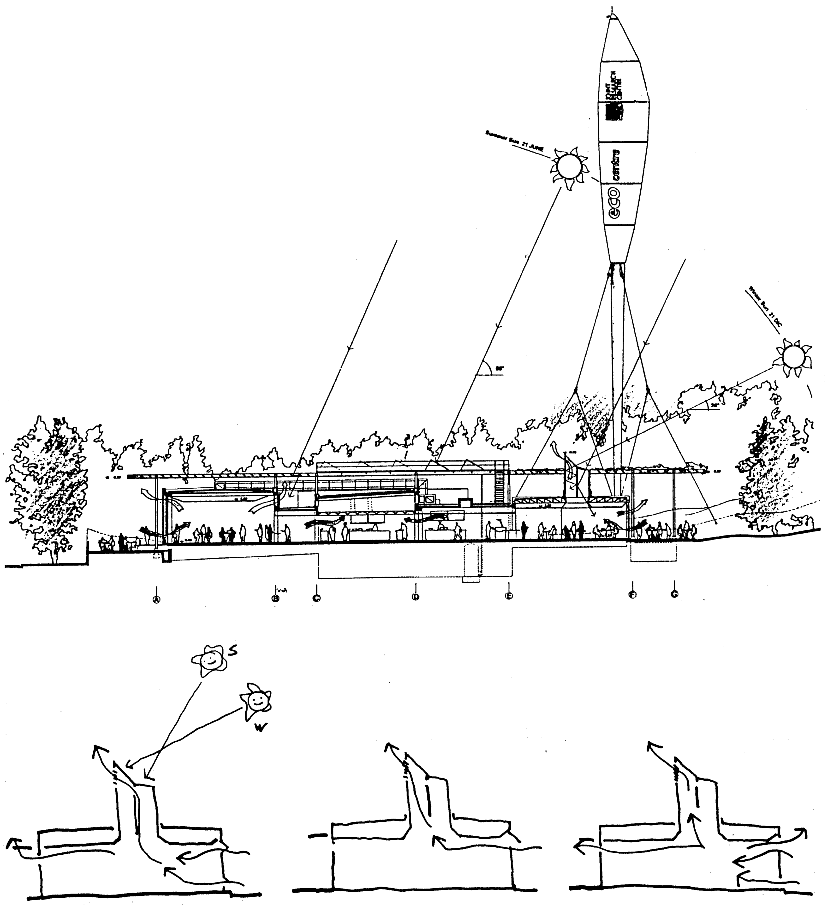

Fig. 13. *Eco Centre Project*: *proposal for a naturally ventilated canteen*, *Ispra*, *Italy* (Mario Cucinella). (a) Longitudinal section. Outside air can enter the spaces through the low level openings and through natural convection rise to exhaust either via the Skylight openings or the high level opening windows. (b) Diagrams showing light reflection and air movement in the Skylights.

of a network linked to a centralised intelligent building management system which controls the total energy use of the building.

3. Greenhouses

A greenhouse as a bioclimatic or architectonic element is generally a south-facing glass volume and may be either an extension or an element incorporated into the construction. The internal space, large or small, acts as a collector and is seperated from the outside by a transparent material, glass or polycarbonate, and from the interior by solid or transparent partitions. This definition is valid for many types of

(c)

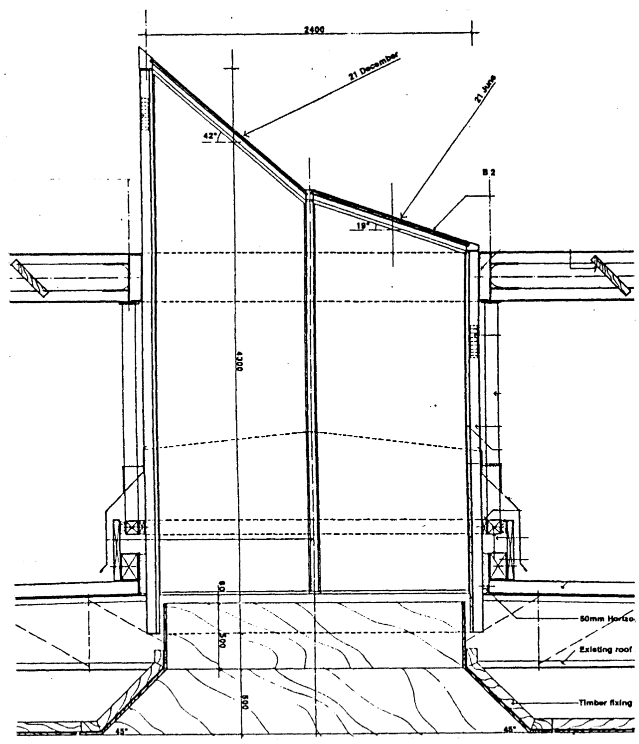

Fig. 13(c). Section through Skylight.

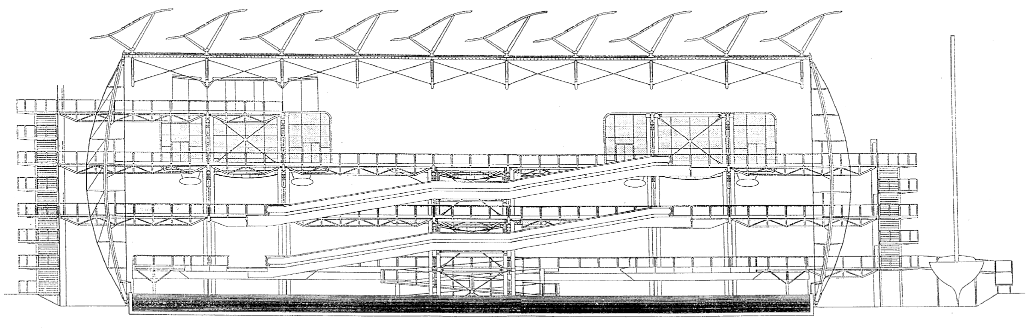

Fig. 15(e). Longitudinal section.

structures, whether for a small veranda extending from the wall of a house or for large internal atria within office buildings since the bioclimatic functions involved are similar in both cases. The form of a greenhouse may vary with the architecture of the building and as such is difficult to classify with predetermined models or standard solutions but varies from openable glazed insertions to auxiliary spaces in a building

such as a veranda or loggia, to enclosed internal courts or patios, to roofing over public spaces between different buildings. Greenhouses generally accumulate heat in thermal masses capable to free it slowly, but they also may be used to heat the adjacent rooms directly. Greenhouses do not generally need to be equipped with auxiliary heating systems; this would be a waste of energy, due to the reduced glazed surfaces thermal insulation coefficient.

In common with multistorey buildings, the presence of vegetation in glasshouses of low-density buildings, even when fitted with simple flower-boxes and an automatic watering system is an enhancing feature and at the same time a natural method of controlling the internal microclimate, whilst in large office buildings the image of internal court transformed into a hanging garden, as in the famous Ford Foundation building in New York has become the solution adopted in certain meritable schemes. The provision of a garden space, with plants and vegetation, within a building located in a congested urban centre creates an environment that surpasses even the benefits of its energy charactristics. In this case the idea of a greenhouse, an extensive area treated as an internal garden, allows a dialogue between the different spaces which address it and also between the people who are working or living there.

In predominantly cold climatic areas, the greenhouse plays a dual role: on the one hand it provides a system of absorption in the periods of direct solar radiation, but essentially they are spaces which reduce heat losses from the building without diminishing the intensity of natural light and allow a more gradual passage from the internal to the external climate. When the covering surface becomes very large, particularly in nordic countries with predominantly cold climates these spaces become partially protected areas which connect different buildings and serve to moderate the extreme external climate, as is evident in many commercial arcades, civic spaces or small 'campus' arrangements comprising independent buildings. If the conservatory space has a purely seasonal utilisation, if occupied solely during the temperate period or is simply maintained at a temperature lower than that of the building interior then the structural masonry which divides it from the inhabited spaces must be thermally insulated.

In other cases the spaces are directly connected to the internal environment, or separated by simple glass panels, and are utilised as permanently habitable spaces and are essentially extensions of the principal building spaces. In this case the temperature of the greenhouse should be regulated using a system of fresh air ventilation, reducing the incident solar radiation, transferring the excess heat to the appropriate structure or thermal mass and adequately insulating the external glass walls during nocturnal hours.

In temperate or warm climates the greenhouse provides protection during the winter months for the relevant volumes of the building (internal courts, terraces, loggias, etc.) which for the rest of the year are, for all intents and purposes, open spaces. In order to achieve this, it is necessary that the closing systems allow a total or partial removal of the glass partitions according to seasonal needs, adopting a technological solution which utilises light materials and are easily manoeuvrable. Moreover, the characteristics of an internal garden have the practical aim of cooling to achieve the necessary environmental conditions using vegetation, which, with its natural process

of evaporation and humidification of the air produces a real effect on the immediate environment further to being a fundamental element for improving quality of life.

The systems for the control of radiation in greenhouses are not dissimilar to those for the general treatment of glazed surfaces or other elements which experience direct gain: movable shading devices may be applied internally or externally to the skin of the greenhouse with total or partial opening systems for the glazed space incorporating, when possible, natural ventilation systems allowing air circulation to moderate excessive overheating.

3.1. *S.A.S. Head Office*, *Frosundavik*, *Sweden* (*Niels A. Torp*)

The S.A.S. (the Swedish national airline) recreation centre is essentially composed of a series of independent, differently articulated buildings linked by a large fully-glazed atrium, glazed throughout its full height. Further to providing natural light to their interiors, this large scale glasshouse made possible the creation of an internal street, where bars, shops and meeting spaces promote an urban ambience. The plants and pools that are to be found along the 'street' each contribute to the provision of a comfortable microclimate combined with the openings in the top of the glasshouse that permit the exhaust of warm, stale air so aiding the cross ventilation of the space.

The buildings front onto the internal street and their visual communication is reinforced by the balconies, terraces and galleries that characterise each block. The external walls and the roof of each different facet is in glass formed by predefined models, assembled utilising a system of joints to minimise thermal bridging. The curtain walls are the patterned, screen-printed sheets of toughened glass which are mounted outside, and at a distance from, the prefabricated, infill wall units which are clad with naturally-anodized, corrugated aluminium sheeting.

3.2. *Domilens Laboratories*, *France* (*Del Sud Associates*)

One of the important designs concepts of this building was to develop an internal area of vegetation thereby generating a filter zone between the offices and laboratories. Consequently there is a concentration of circulation around and through this large winter garden with staircases and connecting galleries at various levels and piping and conditioning services expressed clearly within the space, achieving an overall dynamic effect. The roof comprises curved metal frames which support the glass and which rest on box-section ring beams which are in turn borne by the concrete structure and have an auxiliary function as eaves channels. The large garden is illuminated from above and from two glazed faces, favourably benefitting the internal environment and working conditions. The structure is a grid concrete structure, and the external facade comprises two large glazed surfaces, treated with selective coatings which have a characteristic intense blue colour avoiding possible glare factor.

4. Movable shading devices

One of the major reasons for the evolution and use of shading devices derives from the drive to control the energy consumption for the heating of buildings. In the sphere

of conceptual passive climatisation the physical and geometrical form of the building shell is exploited in order to augment the absorption of solar energy either by passive or active means that may then be modified in order to achieve the appropriate level and system of control. However, the increase of the glazed surface resulting in a large thermal gain during wintertime can create problems of summertime overheating.

The use of shading devices is not new to modern architecture, and no discussion of the same would be complete without a mention of Le Corbusier who from the laboratories at Saint Dier of 1946, the Unit d'habitation in Marseilles of 1949, the Palaces at Chandigarh to the monastery at La Tourette, established the function of bris-soleil as functional integrated building elements. Although the use of fixed shading devices may be swiftly and easily comprehended the acceptance of shading devices as mobile elements has been more difficult: heretofore such elements have been considered as super-imposed on the structure but without becoming visually predominant elements.

In reference to the thermal behaviour of the construction, the more effective choice is that which places the shading devices externally on the facade creating a ventilated cavity therby reducing the heat accumulation of the structure. Generally considered less effective are shading systems located within the space having the sole function of light control; these permit the ingress of the sun's rays, thus heating the air and raising the room temperature through convective heat gain.

Depending on the specific design solution adopted, shading device typologies are so diverse that it is difficult to categorize the possible types other than the obvious distinction between fixed and movable shading devices. In particular the latter may be applied in a specific way to the various parts of the building, the roof, their own structural system or simply as an element applied to the fixed construction. Moreover, the shading may be articulated by devices of varying weights and dimensions, ranging from centimetres to metres, and situated in various positions, either parallel to the facade (generally on south facing elevations), perpendicular (east or west facing) or may be modulated slats parallel to, coplanar with or inclined to the facade.

Movable shading comprises autonomous facade components such as the classic sunbreakers in thin vertical or horizontal slats, as well as elements in various materials and forms which act as part of the external cladding system envisaged by the designer.

Frequently this function becomes incorporated into the structural frame system: from traditional timber shutters to metal awnings, to the slats inserted in the external cladding component as in the facade of the Institute of the Arab World by Jean Nouvel, and finally to the microcomponents inserted directly into the cavity between double glazing and acting with magnetic commands for a gradual reflection and control of the suns rays.

Furthermore, the presence of vegetation; trees and climbing deciduous plants, particularly on the south-facing facade provide an effective form of shading from direct radiation as demonstrated by an endless series of applied examples, both in traditional and contemporary architecture.

Movable shading components obviously have a great advantage in that they may be used according to the climatic situation and the internal requirements, but this possibility has been limited by the necessity of the physical presence of an operator

or has been entrusted to rudimentary automation systems using various devices to exploit the principles of physics. Today the study of the application of shading devices concentrates on the management of shading elements in different climatic and seasonal conditions, through the ever more sophisticated control of the microclimate on one hand and, on the other, through the widespread operational applications (nonetheless being economically compatable with the cost of the building) of an electronic base and of the server mechanism for regulation and command purposes.

A network of sensors connected to an integrated circuit and with some of the server-mechanisms applied to the movable shading devices may independently manage its optimal regulation; they may be extended to ventilation and the insertion of other servicing systems as a function of the internal and external climatic parameters and the imposed requirements.

4.1. *The Institute of Arabian Affairs*, *Paris*, *France* (*Jean Nouvel*)

The building is articulated in volumes of reducing thickness, allowing in all of its parts a view of the outside through filters applied to the glazed walls. One of the most fascinating effects of the design is the play of transparency and reflection of materials, derived from the innovative solution utilising metallic implants in the glazing, whose introduction was generated by particular technological requirements. The south facade comprises panels automatically powered by photo-electric cells, in a way which regulates the opening and diaphragm of the sun-shading elements, as such filtering the light to the interior of the facade more exposed to the sun. The facade towards the Seine presents a density of lines produced by rails suspended level by level from stainless steel rods. The shimmering transparency of the building is continued in the patio which is made of translucent alabaster tiles suspended from fine metal clamps.

The more emblematic element is the south facade of 30×80 m, facing the Science Faculty, and composed of 240 panels in glass and aluminium, framed in a tartan grid of external profiles which continues also onto the adjoining sides but in transparent panels. The light regulating structure is comprised of an aluminium grill, profiled according to the typical decorative motifs of the arab tradition, and inserted between two sheets of glass, of which the innermost is openable for maintenance. The mobile parts are formed by specially shaped concentric metal slats which function like the diaphragm of a camera, progressively closing in order to regulate light with centralised commands and a total of 16,000 mobile elements. Furthermore many internal partitions are made with glazed frames and finished in stainless steel, while the vertical structural frame has been reclad with sheet aluminium.

4.2. *Residential building*, *Malibu*, *California*, *USA* (*A.A.V. Architects*)

The intervention anticipated the transformation of three housing units into a single villa. The designer, having considered the special location of the building whose south elevation is oriented towards the sea, has created a continuous glazed wall, shaded by large fabric fins. The access of light to the internal spaces is mechanically regulated

by the bris-soleil: these elements, by virtue of the position which they assume, regulate the illumination of the interior. The principle structure is formed by a series of trussed beams formed by 200×200 mm box section steel connected to the facade in a precast reinforced concete structure; on these are positioned the various aluminium frames constituting the framework of the PVC fabric, which derive their details from the curtain wall.

4.3. *Belgian Pavillion*, *Seville*, *Spain* (*Driesen-Meersman-Thomaes*)

The rooms of the exhibition are located within a shaded volume of 50×50 m plan dimension with a height of 25 m, whose external structure has been constructed by cylindrical steel columns, 21–25 m tall, disposed according to a 10 m centre to centre grid. The screen of the sunshield, suspended between the slender white columns, create a piazza-patio. The circular steel columns are anchored at ground level to the plinths of the foundation, while at roof level they support the aluminium sunbreaker elements. The structure of the pavilion is made up of laminated timber beams supporting the external sunshading elements: these in turn are supported by steel cylindrical poles onto which are connected a skeleton clad with white impermeable canvas in polystyrene and PVC, tied back at its extremities. The mechanism at some points of the pavilion, is free to rotate, and allows the control of the ingress of light according to the different inclination of the sun's rays.

4.4. *Extension of the Sacred Mosque of the Prophet at Medina*, *Saudi Arabia* (*SL GMBH Rasch & Associates*)

The roof of the Holy Mosque of the Prophet at Medina, in Saudi Arabia, is made by positioning twelve tensile umbrella type structures in two internal courts. Each structure is formed by a supporting column at the summit of which there are hooked four principle poles and eight secondary which, together with a series of internal ties restrain the square shaped membrane. Each umbrella extends to 17×18 m and together with the structure create, in the open position, a light roof above the courts and cleverly resolves the climatic problem of this historic complex, without the burden of grave environmental impact.

The principle which has been adopted anticipates the extension of the membrane in the summer daytime hours for protection against strong solar radiation, while their nocturnal retraction allows the massive walls to expel the heat which has built up during the day. In winter the sequence is exactly the contrary in order to allow the heating of the marble ground and walls, the thermal inertia is preserved during the night by closing the membrane which does not allow the excessive loss of heat from the court. In the closed position the umbrellas assume the form of miniature minarettes complete with spire atop. The opening and the closing of the membranes are regulated by a computerised opening system responding to climatic requirements of different seasons and different atmospheric conditions. In the slow and lingering movement of some tens of seconds, the minarettes reveal their membranal nature through a spectacular manoeuvre, and they close as do flowers, to leave the internal court uncovered.

The retracted structures are also equipped with sensors which inhibits the opening of the devices in winds with a velocity greater than 36 km/h. The supporting columns of each umbrella have been built in marble with copper and artificial stone elements inserted into the capital of the column along with four lamps for nocturnal illumination and two small openings to provide fresh air whilst the umbrellas are in the open position. The sensitivity of this project both to the environment and its historic context displays the potential highs to which a regard for the environment and good design can reach.

5. Light ducts

In the field of illuminance a similar move took place to that in the field of building servicing: the desire for complete control of the internal climate by hermetically sealing the building envelope and the application of artificial means of heating and ventilation, isolating the building from external influences.

This attitude is, nevertheless, changing and is assisted by a rediscovery of the general comprehension of energy problems and the possibility of optimising and exploiting renewable resources in a way which is integrated with contemporary technology.

Furthermore, the development of the technology of artificial lighting that initially prevailed, brought about a general and indiscriminate use of these systems, negating the importance of natural lighting. The attitude which favours sources of artificial lighting is generated by the possibile negative effects on the internal environment by natural lighting for instance the glare factor and overheating produced by uncontrolled suns rays. The almost exclusive use of artificial lighting in the working environment has nevertheless brought about difficulties from the point of view of visual comfort, producing psycho-physical fatigue and lack of motivation, not to mention the elevated cost of management. For these reasons there has been a return to the use of natural lighting, seeking to eliminate the negative charateristics, but above all to integrate natural with artificial lighting by considering the problems of intensity, distribution and colour of the light: natural and artificial lighting do not have to interfere among themselves, they have to coexist in a balanced way in the built environment.

The light which we are able to transfer by natural means to the interior of the construction is an important contribution for human wellbeing. The day-time natural illumination, with its variations in colour and intensity in the course of the day and the course of the year constitute the most basic perception of the passing of time, bringing attention to natural rhythms which may prevent stress or fatigue often provoked by activities carried out in artificially-lit conditions. The perception of the passing of time through the variations of light during the day is basic to our lives and is a fundamental part of the psycho-physical equilibrium of the individual.

More recent study of this type of problem has brought about the theorisation and elaboration of new techniques which seek to convey and radiate the excess of light rather than simply avoiding it. The employment of more advanced techniques of illumination with daylight allow, not only the proportioning of the quantity of light

and its orientation in a uniform way to eliminate some negative aspects such as glare or overheating, but also the receipt of consistent results in the reduction of climatisation costs and savings of electrical energy used for illumination with artificial sources. Challenging the conception that the more effective systems of daily illumination utilise the reflected light from the north sky rather than that directly from the sun, recent research considers the exploitation of the strongest sources of light and the manipulation thereof to obtain optimal results. Furthermore, in reference to artificial light the same criteria may be adopted, such as mirrors which direct rays in an indirect way, avoiding glare and uncomfortable reflections and trying to project light upwards, on the ceilings so as to obtain a uniform distribution.

A particular area, which is still in an experimental phase, is that which attempts to bring light to the interior of the building with materials and new technologies, such as fibre optics to guide the light or interceptors and concentrators of the light and heliostats. Roof mounted mobile receptor elements on which a series of Fresnel lenses can be applied are oriented to the south and connected to an optical duct comprising a sheath of optical fibres which transfer the daylight to the interior of the building. The solutions may be integrated with the architecture of the building without interfering with the construction technique and with a production and installation expenditure compatible with the economic level of the actual servicing system. A foreseeable reduction in the cost of fibre optics and other components of such systems may in a few years allow greater accessability of such interventions and provide a solution to the illumination requirements for interiors, in particular of basements and semi-basement levels. The materials utilised are made up of high efficiency fibre optics of methacrylate polymetals whilst the Fresnel lens is made of a thin plate of cast acetate in which are incised a series of concentric lines which concentrate the sun's rays to a central focus. A movable system commands a solar pointer to maintain the concentration of the rays on the entrance of the fibre optics, which convey the light through a duct with the appropriate adaptors throughout the building. Every optic fibre has a minimum thickness of 250 μm; the bundle crosses the building protected by a flexible sheath.

The diffusion of the light to the internal environment is achieved simply from the extremity of the fibre sheath, where the light exits with an angle of diffusion of about 60°, or alternatively the fibre may be connected to an adaptor for the propogation of light from the ceiling of a room or may be located behind diffusers and lighting fixtures which give a sensation of a window to the outside.

The techniques of transferring natural light to the interior of a building are particularly interesting for the industrial and commercial typology, where the major dimensional extension of the roof in relation to the volume utilised allows the greater part of the interior to be supplied with direct illumination. At any rate, in many buildings it is necessary to relearn the value of daylight, in all of its variations in order to create a more humane environment in what may otherwise be a potentially oppressive workspace.

5.1. *British Council, Madrid, Spain* (*Jestico & Whiles*)

Calle General Martinez is a major avenue running east from Paseo de la Castellana just north of Madrid city centre. Amongst the more recent apartment blocks of the district a few large period villas from the turn of the century, known as 'palacetes', survive.

The building that houses the British Council was originally designed by Ferreras and constructed in 1870 for the Institucion Libre de Ensenanza. A large house of three floors, the building is of classical design with rendered and stucco external walls and slate roof. A series of extensions and modifications to the original elements, such as lean-tos, enlargement of windows and an external escape stairs had obscured the architectural intentions of the original building. The lack of natural lighting internally and an unfavourable internal distribution affected its potential use as a cultural or educational centre. The building was completely reinstated in the following manner: public facilities, library and information space for the arts and sciences were located on the ground floor, with key administrative offices on the first floor and secondary offices on the second. The various lean-tos and additions were demolished, leaving only one block intact, which after careful redesign has been transformed into an arts center, accessible both from an independent access and from the main building through a glazed passage, underlining at the same time its different function and its architectural shape.

The most significant intervention in the internal renovation, which serves to alleviate the dark and oppressive character of the attic storey, is expressed externally by a curved-glass opening placed over the ridge. Beneath this aperture an elliptical void in the form of an inverted cone, pierces the internal space from the roof down to the first floor.

With its axis slightly inclined to the north and east this skylight is oriented to increase the penetration of the morning sun to the interior of the building and a movable panel reduces the solar gain as the day progresses.

To connect the first and second floors a new lightweight stairs in perforated metal was inserted: whilst supplementing an existing stairs to the attic, it creates an alternative means of escape, replacing the stairs removed in the restoration. On the first floor, an oval panel in etched glass, inset into the ceiling, allows light to penetrate down to the ground floor. An excessive thermal gain and problems with glare are overcome by an oval diaphragm, composed of fabric stretched over a metal frame. In the closed position, the light is filtered and the heat which gathers at the top of the building is released in the form of hot air through the top of the inverted cone. In Madrid's cold winter the users can benefit from a certain gain by closing the diaphragm and directing the heated air, by means of ventilation ducts, to the public spaces on the ground floor. Elsewhere the building was reorganized with the insertion of some new partitions and furniture, consistent with the new interventions, with light stell structures, glass and material, in coherence with the new project.

5.2. *Hong Kong Shanghai Bank*, *Hong Kong* (*Foster Associates*)

The Hong Kong Shanghai Bank, as well as experimenting with an advanced construction system utilising a range of specially designed and produced components is a building years before its time in terms of its systems to convey daylight to the interior of the workspace, even when light cannot enter in a natural way through the external skin. The light collection system consists of an external mobile reflecting structure and a fixed internal mirror inside the building. The external suntracking collector formed from two lines of 24 mirrors, varies according to the inclination of the sun by means of active photosensitive cells. The light for reflection is concentrated onto a parabolic reflector situated at the top of the central atrium on the tenth floor from where it is diffused throughout the interior.

6. Integrated ventilation

The facade may be integrated with the servicing of the building in various ways which differ one from the other in the level of complexity of the functions developed by the servicing and by the solar facade. With an increase in the level of functional complexity there is also an increase in the level of 'intelligence' of the control system, and the integration with the servicing systems occurs in one of two ways:

(1) A passive system with a low level of integration, where the facade contributes to the heating and protects against the overheating of both itself and the relative space. The facade generates a flow of warm air which is introduced to the room interior with a priority over traditional servicing providing that the temperature has previously been set to an interval which guarantees the wellbeing of the occupant. For cost control, a simple heating system is considered adequate (for example a radiator) whether natural, manually administered or forced ventilation action is utilised. In such a way the number of control shutters is reduced and the subsystem for automatic control becomes simplified.
(2) Passive integrated systems with heating and ventilation services. The facade is integrated with a heating servicing system comprised of ventilating heaters, which compensate for the loss of energy in each room and from a communal mechanism for each room which compensates for the attendant loss of energy in the flow of external air which must be used for air-exchange. Consequently, the facade provides all the other functions described in the previous case as well as those of integrated ventilation with intake and extraction servicing for the renewal of the air; the number of shutter controls is increased and their management must be automated.

As a rule it is preferable to use insulated glass in geographic zones with a harsh climate, while in other zones it is possible to use single glazing.

The glazed panels are generally mounted in aluminium fixed frames on a profile obtained with laminated pressed steel which is in turn connected to the rear of the loadbearing concrete panel. The double structure allows the three dimensional

adjustment of the glazed walls. The profile in aluminium is composed of a structural frame and beading with the two elements seperated by a continuous gasket which also acts as a thermal break.

6.1. *New Parliament Building at Westminster, UK (Michael Hopkins & Partners)*

The new Parliamentary Building at Westminster will contain 210 offices for the members of parliament and their staff. The building is articulated internally with a central covered court. The offices are located at the perimeter of the building and are characterised by a bay window facade without openings to the exterior due to noise and air pollution problems; the design for the facade is based on a mechanical system of ventilation. At times, the floor formed by elements in precast concrete becomes utilised for thermal accumulation. The contribution of internal lighting is increased by reflective ceiling elements whose utilisation is connected to the external sun shades. The facade is formed by triple glazed panels with a reflective coating; within the frames of the glazing system there are channels for ventilation and for the system of blinds. At roof level bronze anodised aluminium ducts connect to 14 solar chimneys. At the base of each chimney energy is recovered through the use of heat exchangers in connection with the outgoing air; this system preheats the external fresh air which is brought to the interior through small intake grills (it is not recirculated air) and is distributed through channels in the external walls and in the floors. The cooling of the building is obtained by means of heat pumps which utilise water from boreholes 90 m deep, eliminating the use of refrigerants and CFCs.

6.2. *Eco Centre Project: proposal for a naturally ventilated canteen, Ispra, Italy (Mario Cucinella)*

In the field of retrofitting, integrated ventilation is undoubtedly a key issue in the improvement of a building's energy performance.

The retrofitting program outlined by the Ispra Establishment of the Joint Research Centre of the Commission of the European Communities essentially comprises a detailed review and environmental assessment of its site and buildings with a view to reducing energy losses from the entire complex.

In this instance, Building No. 8, the Research Centre's canteen building, is the object of the retrofitting exercise. A single storey building from the 1960s, it has already been extended on a number of occasions and at present accommodates kitchens, serverys, dining areas and a small supermarket. The architectural proposals involved building a 5000 m^2 shading structure over the group of buildings, installing skylights in the canteen and landscaping the areas around the buildings. Prior to considering the ventilation process per se, it is worth noting that many of the architectural interventions initiate the modification of the internal environment, allowing the designer to work from a more moderate base condition: this strategy eases the incipient burden of the ventilation system and represents the holistic approach to retrofitting. The shading roof reduces solar heat gain to the building and, in the case of the canteen areas, this element not only improves thermal comfort conditions but

visual comfort as well, by substantially reducing glare through the existing large glazing surfaces. The newly inserted skylight shafts improve the air movement within the canteen area: ventilation grids will create a vertical flow of fresh air during the summer season.

Previously the two canteen spaces required mechanical ventilation throughout the year: supply air handling units heated or cooled the incoming air as necessary. In the new canteen the installation of the characteristic chimney-shaped skylights with louvred exhaust openings generate a natural process of air exhaustion; in the old canteen this process is permitted by the replacement of clerestory windows with opening lights. Single glazing has been removed from the facade of each canteen area and that which replaces it incorporates high and low level opening lights. Incoming air through low level openings rises by natural convection to exit through the skylight or the high level opening lights. Automatic high level windows and openings are thermostatically controlled but during extremely warm weather the users of the canteen spaces may moderate their own thermal comfort by opening low level windows or doors. The servery and the kitchen mechanical extract system will continue to draw air through the canteen.

7. Cooling technology

Historically, the importance of passive cooling techniques has been manifested in the evolution of different building forms, constructional methods and orientational alignments. From the earliest examples of construction a respect for the natural environment and the extremes of climate has been evident from the hillside Italian villas, taking full advantage of the fresh breezes, to buildings with massive walls and small openings found in various extremely hot climatic regions.

The subject of cooling technology addresses issues ranging from the making of buildings to post-construction applications of cooling techniques. Ideally the issues of cooling should be addressed in the design stage of a building in order to generate a holistic attitude to the reduction of heat gains by the building. Effective cooling not only addresses the removal of heat from the building but also the reduction of heat gains by the building: this may be applied whether in new-build or retrofitting situations.

Air conditioning, still considered a luxury during the 1950s has become a modern 'necessity'—whether or not a reflection of design competance in contemporary building or simply a result of higher expectations of thermal comfort by building occupants. In recent years the widespread use of air conditioning units has occurred parallel with an awareness of their negative climatisational effects on the greater urban environment and the damaging effects of some of the process components. In more northern climates the use of air conditioning has become common in situations where their need is questionable, to say the least. The fragile relationship between the urban climate and summertime energy consumption of buildings for cooling needs is well-trodden territory and has been amply addressed by much research material which has commendably compiled economical and social statistical analyses, projected working and living conditions to identify progressive techniques and possible alternatives. By

utilising one, or a combination of the accepted means of natural ventilation, the building designer can both at the early design stage or in a retrofit situation significantly reduce the cooling load. In northern climates the use of natural ventilation is enough in some cases but with the presence of office equipment the occupant load increases and a further possibility is the use of a method of convective cooling which requires more careful planning to ensure good ventilation routes. Radiant cooling in combination with movable insulation is useful in hot climatic regions where ventilation succeeds only in heating the building and hot external air must be cooled before entry to the building; the building shell is heavily insulated and protected from solar gain and at night the insulation is removed; any heat that has built up during the day is released in the form of radiant energy to the black, night sky, the principle may also be used with a system of heat collectors to gather heat from inside the building and convey it to the exterior rather like a heating system operating in reverse.

Evaporative cooling is perhaps the most effective form of the natural cooling methods, useful in hot areas it takes advantage of the physical principle of latent energy; that is the large amount of energy required to change the physical state of a substance. This is evident in the cooling sensation experienced as ethyl alcohol evaporates from your skin: it is also the same principle on which the refrigerator is based. Apart from the chiller plant of air conditioning units evaporative cooling is not commonly used in buildings because of the obvious constructional difficulties but its effects have been well understood since ancient times as evident in the use of fountains in public spaces and the presence of a pool in the centre of the roman townhouse typology.

Earth cooling involves the construction of part or all of a building below ground taking advantage of the earth as a heat sink to stabilise its internal temperature. In the subterranean settlements to be found in North Africa built-up heat is transmitted by conduction to the earth which is at a lower temperature. A more indirect approach is to pre-cool the incoming air by means of underground ducts or through a subterranean basement storey.

7.1. *Passive cooling techniques*

- Cooling with ventilation: comfort ventilation; convective cooling.
- Radiant cooling: direct radiant cooling; indirect radiant cooling.
- Evaporative cooling: direct evaporation; indirect evaporation.
- Earth cooling: direct coupling; indirect coupling.
- Dehumidification

Cooling performances may be effected by both technolgical elements, such as passive solar components, and architectural elements thereby requiring the incorporation of these techniques into the general conception of building technology.

Investigating the possible integration of Solar Technology into industrial and commercial buildings promotes a more rational use of energy in buildings. Many office buildings, often by nature of what they contain, have a tendency to overheat during the summer; air-conditioning moderates the internal atmosphere but by so doing consumes vast amounts of peak load electricity whilst on an urban scale creates

unfavourable climatic effects. Energy consumption in summer is an increasing tendency in all European countries that can be reduced considerably by the rational use of buildings elements. Due to their extensive use of air-conditioning in the summer season, industrial and commercial buildings are prime subjects for considering the application of energy saving devices. Excessive heat is generated by industrial processes and office and catering equipment, which when combined with extreme summer temperatures results in a constant use of air-conditioning units.

Building devices may act as an intelligent interface between indoors and outdoors, which for the greater part are installed on the 'skin' of the building providing the appropriate thermal and air exchanges necessary for improving indoor conditions. Nowadays many important buildings throughout the world improve thermal conditions by creating this external skin surface with devices which are independent of the other internal parts. The exclusion of unwanted heat is effected by protecting the building from solar radiation, reducing heat gains from the ingress of warm air, by fitting insulation and by the appropriate sizing, positioning and shading of openings.

7.2. *National Museum of Natural Sciences, Florence, Italy* (*L. Macce, G. Maggiora, A. Breschi, A. Cortesi, M. Moretti, M. Sala*)

The decision to design an underground main hall, comprising the central core of the Museum, was assumed in consideration of the historical value of the existing buildings for the city of Florence, which represent an important document of 19th century expansion. The need for natural, top-lighting for the main hall and the desire for an architectural view from the lower level towards the other buildings, suggested the glazed roof solution. Possible strategies to minimise or avoid overheating during the summer season have been analysed, taking into account architectural constraints as well as the representative aspects of this part of the Museum. The solution utilises micronised water as a reflective layer to reduce solar penetration into the building: the white, soft cloud of mist will reflect a large part of the direct radiation, just as clouds and fog operate in nature. The cooling effect of evaporation will remove heat from the roof structure. It is envisaged that the realisation of this solution will be achieved through the use of a pipe network attached to the glazing frames, incorporating micronizers for the creation of the floating cloud and a pod into which drains the water for the cycle of filtration, pressurization and micronization. From the architectural point of view, the water cloud will appear as a virtual floating roof, creating a liquid sculpture for the Museum of Nature. The possibility of operating the system during the night will increase the night cooling of the entire structure.

7.3. *British Pavilion, Expo* 92, *Seville, Spain* (*Nicholas Grimshaw*)

Designed to represent the spirit of Britain, the British Pavilion bears many of the nautical hallmarks of Grimshaw's work: the single layer of the north wall and the internal layer of the south wall are constructed with constant reference to yachting technology using curved steel masts, spreaders and rigging with translucent PVC coated polyester fabric stretched between them. At another level, the building is further enhanced by its demonstration of the concept of cooling; in effect the entire

building could be described as a testament to cooling technology. Prior to the introduction of any mechanical cooling the building utilises various techniques and devices to moderate the extremes of temperature.

Essentially the building encloses a large volume in which there are floating terraces and exhibition pods. The envelope of the building is completely non-uniform with the different elements responding as necessary to the climatic conditions. On the east wall Grimshaw has introduced the water sculpture by William Pye to create a cooling water wall, 65 m long $\times$ 18 m tall. The west wall shields the interior of the building from the full force of the afternoon sun and acts as a thermal store whilst the south wall appears like a line of sails providing the minimal shading required when the sun is at its highest but more importantly allows the air to circulate between the sails and the wall removing built up heat.

8. Outdoor spaces

The sensitivity of human perception to a changing climate, even when of a gentle magnitude is at the basis of study which attempts to determine and define physiological wellbeing in the presence of variable environmental parameters: the temperature and the humidity of the air, its velocity, the presence of thermal radiation from closely surrounding surfaces: these parameters, in the case of external spaces are not only influenced by the built environment but are also added to by the natural where they may either be reduced or reinforced.

The formation of large surfaces of water or dense areas of vegetation are amongst those more community-based interventions with which man has modified the microclimate of external spaces in warm climatic zones. Furthermore, the dimension of the street and its orientation, the ground materials, the form of the spaces, the height of the buildings all play a role in the definition of the external microclimate and within which the limits of other urbanistic and architectural parameters may be utilised in the design phase to achieve the desired results.

The principle of evaporative cooling as discussed previously in the section related to passive cooling plays a major role in the climate modification of outdoor spaces, historical references abound: the use of fountains and water surfaces in hot countries represent a constant architectural tradition; nevertheless it is only with study and recent application that these elements have been utilised in more scientific and precise ways, exploiting their maximum potential.

Evaporation occurs as a natural process, in the presence of water surfaces in environments with low relative humidity or through the transpiration of vegetation but may be promoted with increased air velocity, the emission of water particles using pumps and nebulisers or with the irrigation of surfaces at elevated temperatures, such as roofs, ground surfaces and covers in general.

In the historic context, the pedestrianisation of many historic centres and city districts opens for consideration the newly perceived importance of the street and the square as places of socialising and as a matrix of urban space. The possibilities of human gathering and interaction are facilitated by the characteristics of external space whose success is independent of meteorological characteristics and favour

environmental interventions with bioclimatic technologies and restrained costs; techniques which are compatible with functional and environmental aspects of urban design.

The consideration of external space in bioclimatic design does not signify that every court or open space may be considered a climatic control element: many are the parameters to be satisfied and the considerations which begin with the climate type determine the characteristics of a controllable space in its microclimate. These parameters may be the modifying conditions in the design of external space and represent the variables which define the surrouding climate in every situation, are the same as those which influence architectural design:

- Direct solar radiation
- Temperature of surrouding surfaces
- Air temperature
- Air velocity
- Relative humidity.

In the applications for external space, nevertheless, the specific characteristics of the place of intervention are still more conclusive in the conception of a design, and in spite of the fact that architectural tradition and culture have always considered the themes of external space, there are but few realised examples which demonstrate full competance with the support of study and sufficient scientific investigation. Amongst recent works, one of the more significant must surely be the Expo '92 in Seville, whether from the point of view of investment or the influx of the general public which from the methodological point of view has revealed that there are profound differences between the conventional conditioning systems applied to buildings and the treatment of external space and that in the latter case the servicing systems become a unique design problem which must be confronted from its basis at this time, with accurate investigative instruments. Furthermore, conceptually correct systems of intervention could be inadequate to the specific project application, since carrying out models should not be passively assumed, and every situation shows original parameters and features that should be solved through a collaboration among different specialistic contributions during the whole project development.

8.1. *Shopping centre and offices in Finsbury Avenue*, *London*, *UK* (*Ove Arup Associates*)

The glazing is shaded by vertically slatted bris-soleil, located externally, which also function as service communication trenches for maintenance, acting as diagonal wind-bracing ties at the upper floor levels. The sun shades, made of bronze anodised aluminium are mounted on a system of aluminium beams which extend along the east and west facades. Within the Finsbury building there is a large octagonal atrium, the structure of which is white synthepulvin-coated aluminium. This atrium constitutes the roof of a broad court against which run galleries assigned to offices and public walkways. In the centre and at four corners of the atrium there are sun-shades, the internal frames of which are made of grey aluminium, as are the glazing frames and the handrails. The cleaning and the maintenance of the atrium exterior is assured by a movable scaffold.

The broad covering structure, in which the various office spaces are to be found, contains a piazza internally, which has been conceived and designed not as a circumscribed entity, but in an interchanging relationship with the surrounding buildings and destined to constitute a focal point for recreational and cultural activities, in the sphere of a more broad design for the urban requalification of an area of the city of London. The realisation of this objective has been formalised in a prefabricated load-bearing structure of reinforced concrete which in the upper part houses flowers and timber pergolas and in the lower part contains routes and relaxation points. The theatrical image of the pergola and other ramping levels contribute to the creation of small terraces on the structure of a green oasis, evoking memories of an amphitheatre which descends with terraced seating at the lower levels of the piazza where the shops and services are concentrated to feed the metropolis.

8.2. *El Palenque*, *Exhibition Structure*, *Expo* 1992, *Seville*, *Spain* (*J. M. De La Prada Poole*)

El Palenque is a large space covered by a tensile sail structure, which has housed numerous performances/exhibitions and cultural entertainment during the course of the Expo at Seville. The lower part of the area was comprised of two connected piazzas, with clearly differentiated characteristics. The first elevated on its plinth of about one metre, bordering the second by three sides forming a belt of seperation between it and the pedestrian avenues. It is treated as a shaded and fresh area protected from the surrounding context by four barriers; two of vegetation and two of water nebulisers and fountains. The second piazza, to the interior of the former, constitutes the performance space proper. Its general organisation and disposition of the vegetation areas at the front attempts to recreate the idea of a roman theatre. For complete shielding against the suns rays large roofs and sails in PVC have been utilised, positioned with tensile structure systems above metal openwork. The form of the tense membrane itself suggested locating hot air extractors, similar to gigantic upturned funnels, on top of the structure together with water nebulizers so as to create evaporative towers that are able to lower the temperature of the air close to the ground. To control the external overheating of the membrane, an evaporative cooling method has been used with a continuous irrigation produced by microperforated on the surface facing the sun.

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